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Species Profiles: Life Histories and Environmental Requirements (Gulf of Mexico)

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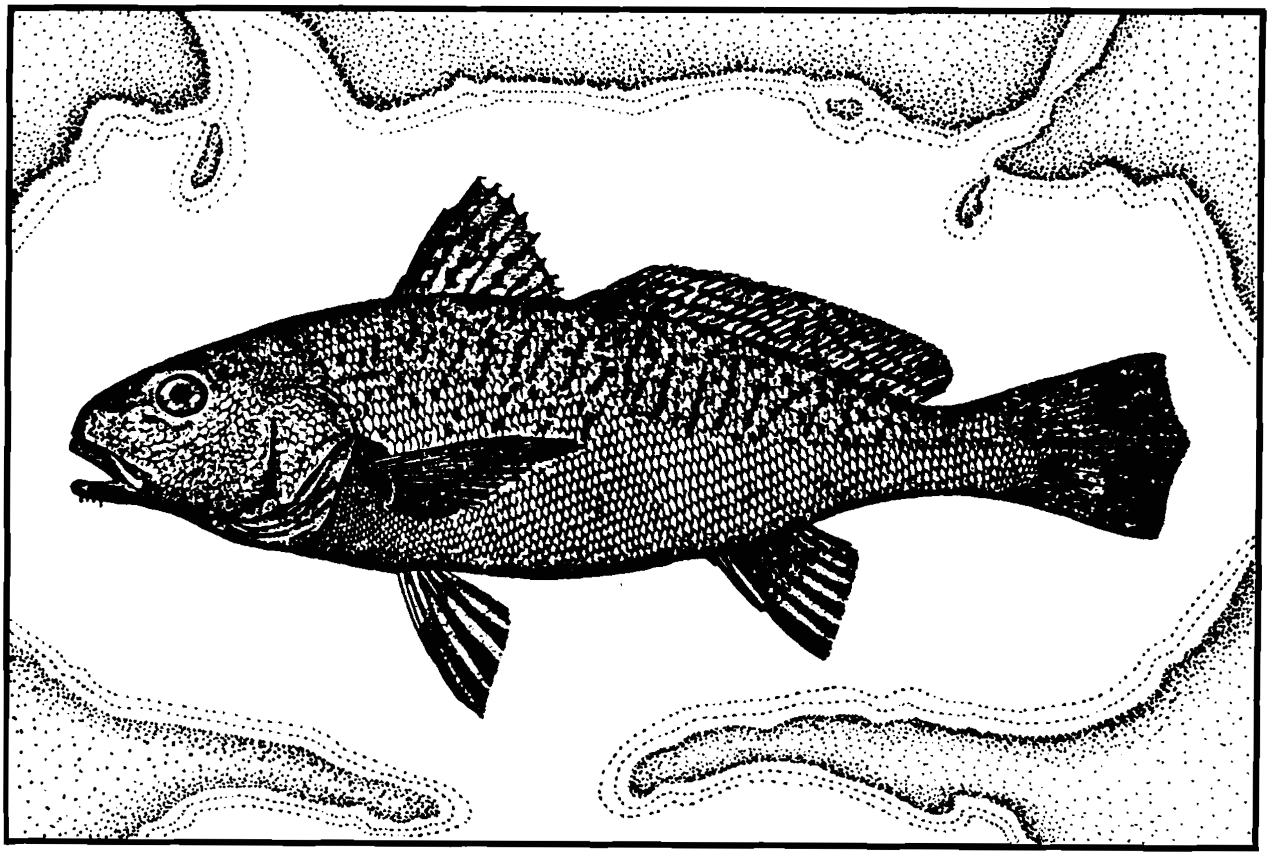

Fish and Wildlife Service
U.S. Department of the Interior

Waterways Experiment Station
Coastal Engineering Research Center
U.S. Army Corps of Engineers

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Species Profiles: Life Histories and Environmental Requirements (Gulf of Mexico)

ATLANTIC CROAKER

by

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PREFACE

This series of profiles about coastal aquatic species of commercial, sport, and/or ecological significance is being jointly developed and funded by the U.S. Army Corps of Engineers and the U.S. Fish and Wildlife Service. It is designed to provide coastal managers, engineers, and field biologists with an introduction to the subject species and a synopsis of the information necessary to relate expected changes (associated with coastal development) in the physicochemical characteristics of estuaries to changes in these selected biological populations. Each profile includes brief sections on taxonomy and identification followed by a narrative of life history, environmental requirements, ecological role, and (where applicable) the fishery of the subject species. A three-ring binder is used for this series to facilitate additions as new profiles are prepared.

Suggestions or questions regarding this report should be directed to:

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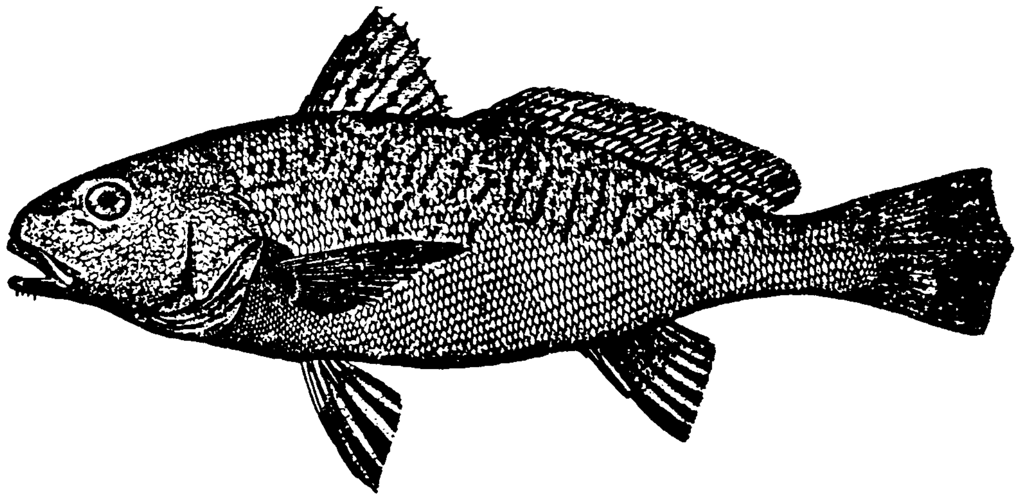

Figure 1. Atlantic croaker.

ATLANTIC CROAKER

NOMENCLATURE/TAXONOMY/RANGE

Scientific name . . . . . *Micropogonias undulatus* (Linnaeus)[1]
Preferred common name . . . . Atlantic croaker (Figure 1)
Other common names . . . . . . Croaker, crocus, hardhead, King Billy, la corbina
Class . . . . Osteichthyes
Order . . . . Perciformes
Family . . . . Sciaenidae

Geographic range: Coastal waters from Cape Cod, Massachusetts to the Bay of Campeche, Mexico, uncommon north of New Jersey. Common along the entire Gulf of Mexico coast but most abundant off Louisiana and Mississippi (Figure 2).

MORPHOLOGY/IDENTIFICATION AIDS[2]

D. X + I, 28-29; A.II, 7-8; Sc. 64-72; Gr. 7 + 28-29; A.II, 7-8; Sc. depth 2.9-3.65. Body elongate, compressed; back moderately elevated; head rather long; snout conical, projecting beyond the mouth in the adult and proportionately much longer than in the very young, 2.85 to 3.75 in head; eye 3.35 to 4.8; interorbital 3.35 to 3.8; mouth moderate, horizontal, inferior; maxillary reaching a little past front

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[1]Changed from *Micropogon* (preoccupied by *Micropogon* Boie 1826 in Aves) by White and Chittenden (1977).

[2]Largely extracted from Hildebrand and Schroeder (1928), Pearson (1929), and Hoese and Moore (1977). See these references for explanations of abbreviations and measurements.

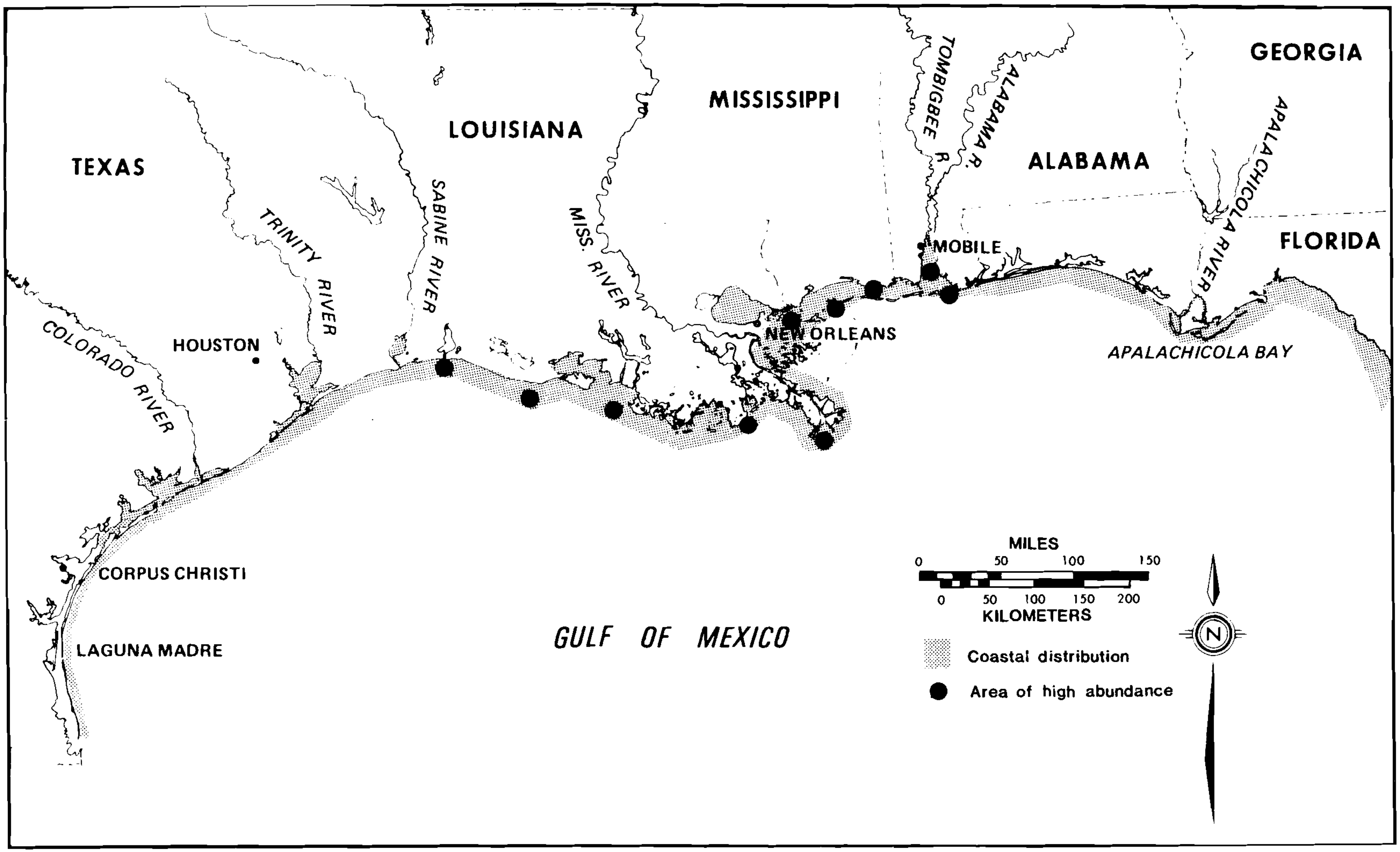


Figure 2. Distribution of Atlantic croaker along the Gulf of Mexico coast.

of eye to below middle of eye, 2.3 to 2.85 in head; teeth in the jaws all small, in broad villiform bands; chin with several pores and a row of short, slender barbels on each side; preopercle with strong, short spines on margin; gill rakers short; scales moderate, reduced anteriorly above lateral line, strongly ctenoid, extending on the caudal but not on the other fins; dorsal fins contiguous, or more or less continuous in young, the first composed of slender spines, somewhat elevated, the third and fourth spines longest, higher than any of the rays in the soft part; caudal fin slightly double concave in adult, with the upper and middle rays longest, sharply pointed in very young; anal fin small, with two strong spines, the first very short, the second about two-thirds the length of the soft rays; ventral fins moderate, inserted under and slightly behind base of pectorals; pectorals rather long in adult, reaching well beyond tips of ventrals, scarcely reaching tips of ventrals in young, 1.15 to 1.5 in head.

Color in life: greenish or grayish silvery to brassy yellowish and highly irridescent above, silvery white below; back and sides with many brassy or brownish short, irregular, oblique bars formed by spots on scales. Bars may become less distinct in larger adults. Young usually paler, silvery. Larval and postlarval forms are described by Pearson (1929).

REASON FOR INCLUSION IN SERIES

The Atlantic croaker is one of several sciaenid fishes in coastal Gulf of Mexico waters that are subject to significant commercial and sport fisheries. It is the target species of an industrial groundfish fishery and is often dominant in inshore and offshore sport catches. The species is considered estuarine dependent as all stages from larvae to adults are known to occur in abundance in estuarine waters. Postlarvae and juveniles grow rapidly in estuarine nursery grounds and are subject to predation by several other species. Although quantitative information is lacking, it is likely that croakers play a significant role in estuarine trophic dynamics.

LIFE HISTORY

Spawning

Spawning by the Atlantic croaker has never been observed. The site and time of spawning are therefore inferred from the capture of ripe adults or early developmental stages. Most published works agree with the early work of Pearson (1929), who suggested that spawning occurs in the open gulf "near the mouths of the various passes that lead into the shallow bays and lagoons." Bearden (1964), however, maintained that croakers along the South Carolina coast spawn entirely in the ocean as he found ripe females as far as 48 km (30 mi) offshore. Hildebrand and Cable (1930) also reported taking very young croakers 24 km (15 mi) offshore. Spawning is reported to occur within a depth range of 7.8 to 81 m or 26 to 266 ft (Fruge and Truesdale 1978).

The Atlantic croaker, as with other sciaenids, has a protracted spawning season. Within its entire range, larval and postlarval stages have been collected in passes and bays from as early as August in Chesapeake Bay (Hildebrand and Schroeder 1928) to as late as June in Louisiana (Suttkus 1955). The normal range for the Gulf of Mexico, however, appears to be from October to March with a peak in November (Pearson 1929; Gunter 1938; Parker 1971). Although Pearson (1929) reported "deluges of larvae . . . ," little information was found on the very important life history trait and modeling parameter of fecundity, and those few literature reports vary widely. For a female of 395 mm total length (TL)[3], Hildebrand and Cable (1930) reported 180,000 uniform size eggs, but Hansen (1970) reported only 41,200 eggs. No explanation for this disparity has been found. Eggs are pelagic and hatch in less than 1 week (Hildebrand and Cable 1930; Gutherz 1976).

Larval Stage

After hatching, larvae and postlarvae may spend some time in the plankton (Hildebrand and Cable 1930), but apparently soon become demersal (Hildebrand and Cable 1930; Fruge and Truesdale 1978). A demersal habit would concur with Pearson's (1929) observation that larvae were caught primarily in the deeper waters of the passes. It is unclear whether the movement of larvae into the estuaries is passive or active or a function of both. Perkins (1974) stated that "the reaction current may carry the newly hatched fish over 100 miles upstream to the upper limits of the saltwater intrusion . . . this first movement is passive." However, Pearson's (1929) observations of postlarval croakers suggest that the movement is, at least in part, an active process. He stated, "A determined attempt. . . to gain the shelter of the bays was observed on many occassions. Few fish could breast the strong current of the ebb tide, but the young croakers, massed in schools, were seen attempting to enter the passes by hugging the sides of channels and to take advantage of the slower currents." This schooling behavior is maintained throughout life.

Postlarvae and Juveniles

Once in the estuaries, the postlarvae and very young spread throughout with heaviest concentrations at the headwaters (Pearson 1929; Gunter 1938; Parker 1971). Specific areas of abundance for Lake Borgne, Louisiana, and Galveston Bay, Texas, were identified by Parker (1971), but he stated more generally that areas of concentration were "always in shallow water less than 1.2 m deep and in close proximity to a source of freshwater or brackish water which generally flowed through marshes or tidal flats." The Gulf of Mexico Fishery Management Council (GMFMC 1981) reported abundant juveniles in the cordgrass (*Spartina alterniflora*) marshes of Louisiana in both open and vegetated areas of 1 m or less and stated that "brackish marsh is thought to be very important to juvenile development" (but see Substrate section).

Young croakers remain in estuarine nursery areas at least through spring and early summer (growth and diet during this period are discussed later) before migrating to the gulf waters. Parker (1971) suggested that emigration may begin as early as April (Texas) or June (Louisiana) with the attainment of 60 to 85 mm TL. The significance of these lengths, however, was not discussed, and later in this same report he stated that peak gulfward migration in Louisiana occurs from September to November. October to November is the most commonly cited peak migration period from the Gulf of Mexico (Gunter 1938; GMFMC 1981) and also (at least for Louisiana) the period of greatest average drop in surface water temperature between successive months (Barrett 1971). Nearly all reports suggest that this seaward migration is tied closely to decreasing temperatures in the estuaries (Pearson 1929; Gunter 1938; Wallace 1940; Parker 1971; GMFMC 1981). However, Etzold and Christmas (1979) stated that "migration generally starts in summer and peaks with decreasing temperatures in the early fall." If this and the earlier dates suggested by Parker (1971) are correct, temperature decrease may not actually "trigger" the migration, but instead sufficiently accelerate those processes

[3] 25.4 mm = 1 inch.

that provide a common association of "peak" migration with periods of rapid temperature change.

Seaward migrating young-of-the-year are subject to depletion by both shrimp and groundfish fisheries (Pearson 1929; GMFMC 1981) operating in the open gulf waters. A single, very tentatively suggested estimate of instantaneous fishing mortality (F) is given by GMFMC (1981) as 1.0, or an annual expectation of death due to fishing of 63%. However, no comparison of F with instantaneous natural maturity (M) was found in the literature.

Maturity and Life-Span

Most authors maintain that croakers mature at the end of their second year (Pearson 1929; Gunter 1945; Johnson 1978), but others report that some may mature and spawn before their second year is completed (Avault et al. 1969; Hansen 1970; Etzold and Christmas 1979). Wallace (1940) reported that males mature at 2 years and females at 3 years of age. Surviving spawners and juveniles (by then the 1+ yr-class) overwinter in the gulf and return to the estuaries the following spring. The cycle may repeat several times during the lifetime of a single fish, as at least some members of the species live to 4 to 5 years of age but rarely greater (Parker 1971; Etzold and Christmas 1979).

No one has suggested that this species dies after spawning, and there have been no reported observations of massive numbers of spent Atlantic croaker carcasses (e.g., in trawls, along shore) as is common for salmonid and osmerid species of more temperate waters. However, from earliest authors there has been the hint of high post-spawning mortality. Pearson (1929) reported that after spawning in the fall of their second year, croakers "return in small numbers" and that it "may be that most croakers die after spawning." This observation is echoed by Gunter (1938), Parker (1971), and others. It is possible that this observation may simply be a false impression resulting from a normally high natural mortality or high over-winter fishing mortality or both. As mentioned above, however, almost no information exists on mortality or on the percentage of returning spawners.

GROWTH CHARACTERISTICS

Parker (1971) reviewed the literature on the growth of croakers. He reported averages from these studies to be 12.1 mm/mo TL (145 mm/yr) in the first year, 5.3 mm/mo (64 mm/yr) in the second year and 3.6 mm/mo (43 mm/yr) in the third year. In his own study, the slope of the length-weight regression curve was significantly greater than three (according to the "cube law" of isometric growth). Parker attributed this to increasing condition with increasing size rather than to allometric growth. His length-weight regression equation for croakers from Galveston Bay, Texas, was:

$$\log W = -5.21 + 3.10 \log L$$

where: W = preserved wet wt (g) (no conversion equation for live wt/preserved wt was given)

L = total length (mm)

Parker's finding of a relatively low mean condition factor for croakers in summer appears to support the observation of Hildebrand and Cable (1930) that growth rate in the croaker is highest in spring and fall. Parker also discussed year-to-year and geographic variation in growth rate. While year-to-year variation was apparent, he presented no convincing evidence of geographic variation. The only two growth studies conducted in the same year (one in Florida, one in Texas) showed similar results.

COMMERCIAL AND SPORT FISHERIES

The Atlantic croaker is the primary target species of a multispecies groundfish fishery in the Gulf of Mexico (GMFMC 1981). Commercial fishing is centered in a "primary area" (Point AuFer, Louisiana, to Perdido Bay, Florida). Most of the commercial catch used for human consumption is landed in Alabama (see Table 1). The Gulf of Mexico Fishery Management Council (1981) estimated that groundfish in this primary area are being exploited at or near the estimated maximum sustainable yield (MSY) of 486,000 mt, but "the greatest proportion (approximately 300,000 mt) is the incidental, unwanted catch and discard of the shrimp fishery." Total annual landings by the directed groundfish fisheries are about 56,000 mt, approximately 69% of which is Atlantic croaker. Groundfish MSY for the entire gulf (within the U.S. 200-mi Exclusive Economic Zone) was estimated (for 1981) at 1,070,000 mt, optimum sustainable yield (OSY) at 819,160 mt and expected annual domestic harvest at 699,680 mt. The canned petfood industry is the primary user of the groundfish catch. Other uses of commercial groundfish include fishmeal and the developing Surimi industry which produces domestic and foreign (Japanese) Kamaboko (sausage). None of the fishes which form the bulk of the groundfish stock has an assigned legal status and the fishery remains unregulated. Recent (1974-80) declines in total landings and catch per unit effort (CPUE) of the industrial fleet were reviewed by the GMFMC who have presented a management plan suggesting remedial actions. The plan has not yet been adopted.

The croaker also supports a substantial sport fishery although it is usually considered a less preferred species than several other sciaenids (e.g., spotted seatrout, black drum, and red drum). In 1970, the marine sport catch of croaker for the Gulf of Mexico was estimated at 28,483 mt,

Table 1. The weight and value of the commercial catch (for human consumption) of Atlantic croaker from the Gulf States and other areas in 1976 (National Marine Fisheries Services, U.S. Fishery Statistics for 1976).

Location	Weight (mt)[a]	Value (dollars x 10^3)[b]
Florida west coast	466	179
Alabama	2864	874
Mississippi	191	61
Louisiana	156	45
Texas	51	11
Gulf of Mexico (total)	3278	1170
United States (total)	14,331	3821

[a]Weight = round (live) weight, mt = metric tons (2204.6 lb).

[b]Value = gross dollars to the fishermen (exvessel prices).

nearly nine times the 1976 commercial landings for human consumption in the same area (the most recent years that data were available). Both commercial and sport catches are best from early summer to late fall (Gunter 1938; Kobylinski and Sheridan 1979; GMFMC 1981). The commercial catch is largely composed of 0+ and 1+ age groups (Etzold and Christmas 1979; GMFMC 1981). Croakers over 2 years old are largely limited to the sport fishery. Croakers are caught in estuaries and bays by small boat fishermen, but many are also taken near offshore oil platforms (Gutherz 1976).

Etzold and Christmas (1979) concluded that croakers in the Gulf of Mexico represent a single stock. However, the mechanism for maintenance of stock integrity seems unclear as they further suggested that there are consistent size differences (not mentioned by Parker 1971) between fish caught on either side of the Mississippi River and that there is little longshore migration. It seems necessary for proper management in the future to clarify the issue of a single versus multiple stocks, especially in light of the disparate levels of fishing pressure (GMFMC 1981) received by the croaker and other groundfish species in various areas of the Gulf of Mexico.

Both GMFMC (1981) and Etzold and Christmas (1979) reported a wide year-to-year fluctuation in apparent croaker abundance. GMFMC (1981) further suggested that such fluctuations "imply environmental conditions have had and will continue to have a strong impact on the stock. . . ." Although environmental conditions historically may have played the major role in determining stock abundance, GMFMC (1981) also suggested that the exceptionally high groundfish harvests (primarily as shrimp by-catch) in 1975-76 "may have had a detrimental influence on the production of potential recruits in 1977." They additionally warned that although this cannot be determined based on the available information, "lack of information should not cause the warning signal to be ignored."

ECOLOGICAL ROLE

The Atlantic croaker as a species cannot be assigned to a single trophic level, as dietary shifts occur during their lifetime (Darnell 1958, 1961). Darnell (1958) described four active feeding stages, but later (Darnell 1961) presented only three (see Table 2). While feeding habits between these stages may be fairly distinct, feeding within stages is apparently rather nonselective (Parker 1971).

No information was found on the duration of the yolk sac stage or whether or not active feeding begins during or only after this stage. Larval and postlarval croakers are largely zooplanktivorous and may be considered secondary consumers. Several authors have reported detritus to be a major component of the juvenile diet (Darnell 1961; Parker 1971; Etzold and Christmas 1979). Etzold and Christmas (1979), in addition to the items listed in Table 2 (footnote b), also mentioned miscellaneous plants. It is possible then that croakers may play a minor role as primary consumers, but it is not clear that ingested plant material (whether discrete or detrital) is assimilated. Other than the initial zooplanktivorous stage, all sizes of croakers are reported to ingest benthic microinvertebrates. This is consistent with the laboratory observations of Roelofs (1954), who found that croakers "dived deeply into the bottom with some force, digging as they fed, and were thus able to obtain subsurface material." Adults appear to feed similarly to juveniles, but are also capable of taking larger invertebrates and fishes. As juvenile and adult, therefore, the croaker may operate as a secondary, tertiary, or higher level consumer. The importance

Table 2. Food habits of three size classes of Atlantic croaker, *Micropogonias undulatus* (by percent of diet).[a]

	Size class (mmTL)		
Food category	10-49	50-124	125-325
Zooplankton	54	12	-
Detritus	22	57	31
Microinvertebrates[b]	24	21	35
Fishes[c]	-	6	14
Macroinvertebrates[d]	-	-	19

[a]Tabular data from Darnell (1961). No mention was made of the method for estimation of percent diet.

[b]Includes isopods, amphipods, chironomid larvae, small clams, mussels, small crabs (others have included polychaetes, harpacticoid copepods, foraminifera, ostracods, minute snails, and coleopteras).

[c]Includes ophichthid eels, pipefish, sheepshead minnows (others have included small croakers, gobies).

[d]Includes *Rangia* clams, mud crabs, blue crabs, grass-mud-river shrimps (others have included the commercial penaeid shrimps).

of each of the various feeding stages of croakers as consumers depends upon their number and rate of ingestion. No quantitative study of the role of croakers in estuarine trophic dynamics was found in the literature.

At a community interaction level, croakers have been recorded as prey for larger fishes including larger adults of their own species (Pearson 1929; Gowenlach 1933), but again the quantitative importance of the croaker as a prey item is not known. Parker (1971) concluded from diet and distributional overlap data that "spot and croaker were found to be in direct competition." There is, however, no experimental evidence to support such a conclusion, and the use of overlap data to infer competition is clearly insufficient and open to misinterpretation (Colwell and Futuyuma 1971). Gulf of Mexico Fishery Management Council (1981) discussed the shrimp-associated communities of Gulf of Mexico groundfishes. Their definition of the groundfish "stock" as a group of species with "similar life histories . . .and common habitat requirements" is similar to the guild concept as defined by Root (1967). They further suggested that "unchanged relative abundance [of species comprising the groundfish stock] . . . suggests stability in the groundfish ecosystem."

ENVIRONMENTAL REQUIREMENTS

Temperature

The role of temperature as a key to the fall emigration of croakers from estuaries has already been discussed. Rising temperatures (16°C [61°F] or more) may also induce immigration inshore during spring (Johnson 1978). Field and laboratory data both indicate that juveniles are more tolerant of lower temperatures than adults. Parker (1971) reported that juveniles have been taken in waters from 0.4° to 35.5°C (33° to 96°F) as compared to 5° to 35.5°C (41° to 96°F) for adults. Laboratory tests established lower and upper lethal temperatures of 0.6° and 38°C (33° and 100°F) for juveniles, and 3.3° and 36°C (38° and 97°F) for adults, respectively (Schwartz 1964). Sudden and prolonged cold snaps which occur while the croakers still inhabit the shallower estuarine areas can cause mass mortalities (Hildebrand and Cable 1930; Gunter and Hildebrand 1951). Parker (1971) found the highest abundances of croakers in waters from 21° to 25°C (70° to 77°F), but stated that "most months, croakers appeared to be rather evenly distributed over the range of available temperatures" except that older fish (over 1 year old) were largely absent in waters below 10°C (50°F). Postlarvae were taken in waters from 6° to 20°C (43° to 68°F), but a wider tolerance range was suspected. Parker (1971) also suggested that croaker can grow well at temperatures from 12.8° to 28.4°C (55° to 83°F) and possibly from 6° to 32°C (43° to 90°F).

Salinity

Croakers have been collected in waters from very dilute (0.2 ppt) to hypersaline (75 ppt) (Simmons 1957; Parker 1971). The survivorship of croakers at the upper end of this range is unknown and occurrence in such waters is uncommon. Parker (1971) stated that "the nature of the life history of the Atlantic croaker requires that postlarvae and juveniles be adaptive, not only to a comparatively broad salinity range, but also to relatively rapid salinity changes." No information was found on the latter, but larvae and juveniles have been taken in salinities ranging from near 0 to 36 ppt. Etzold and Christmas (1979) reported that croakers were taken from all ranges of salinity in Mississppi waters with biggest catches in waters from 15 to 19 ppt. Parker (1971) cautioned that many observed tendencies to lower salinity water may be easily interpreted as habitat preference for features other than salinity. This may be the case with the observation of Kobylinski and Sheridan (1979) that croakers were "noticeably absent from the higher salinity (avg. 19.2 ppt) grass bed stations" (but see Substrate section). No reports of significant penetration into freshwater were found in the literature.

Depth

Immediate post-settlement and nursery depths have been discussed in the Life History section as have suspected spawning depths. Gulf of Mexico Fishery Management Council (1981) reported that groundfish stocks in the Gulf of Mexico occur at highest densities in waters of less than 91 m (300 ft). During the warmer months most are in waters less than 18 m (60 ft). Winter stock concentrations are greatest in 18 to 55 m (60 to 180 ft). In Louisiana waters west of the Mississippi River, croakers dominated to 46 m (150 ft). Near the mouth of the river they dominated to a depth of 91 m (300 ft), migrating in winter to depths of 64 to 110 m (210 to 360 ft). The effects of this winter migration on the species composition of white and brown shrimp-associated communities are also discussed by GMFMC (1981). Deep navigational channels may be used heavily by immigrating larvae and postlarvae in winter months (Wallace 1940), but Parker (1971) reported that he generally found the fewest juvenile croakers in such channels and concluded that they did not serve as nursery areas. No reference to sexual differences in depth selection among croakers was found.

Substrate

No experimental studies of substrate preference by croakers were found in the literature. Information presented here is inferred from field observations and should thus be considered a statement of association and not necessarily preference. Beyond the planktonic stage, virtually all sizes of croakers are most often associated with soft bottoms (Pearson 1929; Gunter 1938; and others), particularly those containing large quantities of detritus (Parker 1971). Juveniles have been reported (GMFMC 1981) to occur abundantly in both open and vegetated shallow (about 1.2 m [4 ft] or less) marsh areas. Kobylinski and Sheridan (1979), however, found few croakers in areas of dense benthic macrophytes. It is unclear whether this discrepancy between the two reports is real or due to differences in sampling technique. Adults are associated with similar mud or mud-sand substrates in somewhat deeper waters and often, unlike juveniles, inhabit navigational channels. Adults have also been collected over oyster, coral, or sponge reefs (Johnson 1978) and near bridges, piers or similar structures (Gunter 1938; Gutherz 1976; GMFMC 1981).

Other Environmental Factors

No published information on the dissolved oxygen requirements of croakers was found. Other than the previously quoted observations of Pearson (1929) and Perkins (1974) in reference to larval immigration, no information specifically addressing water velocity was found. Perkins (1974) further noted that postlarvae, upon reaching their furthest point upstream, "gather and move downstream [seaward] as they grow . . . the movement downstream is an active process." No mention is made of orientation during such movements or whether they are genetically determined or related to particular environmental cues. Kobylinski and Sheridan (1979) in their study of spot and croaker commented that the reproductive pattern of croakers might have evolved such that occurrence of planktivorous stages (up to 15 mm) coincides with peak river flow and "may depend on annual flooding." Should this be the case, alteration of normal seasonal runoff pattern (e.g., by flood control measures, dams) might be expected to affect croaker production.

Although no study specifically addressing larval croakers was found, Stern and Stickle (1978), in a review of the effects of turbidity and suspended material in aquatic environments, concluded that within a given species, the early developmental stages generally were more sensitive to concentrations of suspended solids than were adults. Kobylinski and Sheridan (1979) found croakers to be particularly abundant in areas "influenced by a highly turbid runoff." Parker (1971) also noted a tendency toward higher croaker densities in turbid areas. He attributed this observation to increased food availability and the possibility of predator protection afforded by decreased visibility.

To date, over 90 parasites and/or diseases have been identified from the croaker (Etzold and Christmas 1979). Several of the larval nematodes "would present a human health problem" only if eaten raw (Etzold and Christmas 1979). The effects of these parasites and diseases on the survival and growth of croakers are not yet known.

LITERATURE CITED

Avault, J.W., Jr., C.L. Birdsong, and W.G. Perry. 1969. Growth, survival, food habits and sexual development of croaker, Micropogon undulatus, in brackish water ponds. Proc. Southeastern Assoc. Game Fish Comm. 23:251-255.

Barrett, B.B. 1971. Cooperative Gulf of Mexico estuarine inventory and study, Louisiana: Phase II, Hydrology and Phase III, Sedimentology. Louisiana Wildlife and Fisheries Commission, New Orleans. 191 pp.

Bearden, C.M. 1964. Distribution and abundance of Atlantic croaker, Micropogon undulatus, in South Carolina. Contrib. Bears Bluff Labs 40:1-23.

Colwell, R.K., and D.J. Futuyuma. 1971. On the measurement of niche breadth and niche overlap. Ecology 52(3):567-576.

Darnell, R. 1958. Food habits of fishes and large invertebrates of Lake Pontchartrain, Louisiana, an estuarine community. Publ. Inst. Mar. Sci. Univ. Texas. 5:353-416.

Darnell, R. 1961. Trophic spectrum of an estuarine community, based on studies of Lake Pontchartrain, Louisiana. Ecology 42(3):553-568.

Etzold, D.J., and J.Y. Christmas. 1979. A Mississippi marine finfish management plan. MS-AL Sea Grant Consortium MASGP-78-046.

Fruge, D.J., and F.M. Truesdale. 1978. Comparative larval development of Micropogon undulatus and Leiostomus xanthurus (Pisces: Sciaenidae) from the northern Gulf of Mexico. Copeia 1978(4):643-648.

Gowenlach, J.N. 1933. Fishes and fishing in Louisiana. La. Dep. Conserv. Bull. 23.

Gulf of Mexico Fishery Management Council (GMFMC). 1981. Draft fishery management plan environmental impact statement and regulatory analysis for groundfish in the Gulf of Mexico. GMFMC, Tampa, Fla.

Gunter, G. 1938. Seasonal variations in abundance of certain estuarine and marine fishes in Louisiana, with particular reference to life histories. Ecol. Monogr. 8(3): 315-346.

Gunter, G. 1945. Studies on marine fishes of Texas. Publ. Inst. Mar. Sci. Univ. Texas. 1:1-190.

Gunter, G., and H.H. Hildebrand. 1951. Destruction of fishes and other organisms on the south Texas coast by the cold wave of January 28-February 3, 1951. Ecology 32(4): 731-736.

Gutherz, E.J. 1976. Northern Gulf of Mexico groundfish fishery, including a brief life history of the croaker (Micropogon undulatus). Gulf Caribb. Fish. Inst. 29:87-101.

Hansen, D.J. 1970. Food, growth, migration, reproduction, and abundance of pinfish, Lagodon rhomboides, and Atlantic croaker, Micropogon undulatus, near Pensacola, Florida, 1963-65. Fish. Bull., U.S. 68(1):135-146.

Hildebrand, H.H., and L.E. Cable. 1930. Development and life history of fourteen teleostean fishes at Beaufort, North Carolina. Bull. U.S. Bur. Fish. 46:383-488.

Hildebrand, H.H., and W.C. Schroeder. 1928. The fishes of Chesapeake Bay. Bull. U.S. Bur. Fish. 43 (Part I):1-366.

Hoese, H.D., and R.H. Moore. 1977. Fishes of the Gulf of Mexico: Texas, Louisiana, and adjacent waters. Texas A&M University Press, College Station.

Johnson, G.D. 1978. Development of fishes of the Mid-Atlantic bight: an atlas of egg, larval and juvenile stages. Vol. 4. Carangidae through Ephippidae. U.S. Department of the Interior, Fish and Wildlife Service. FWS/OBS-78/12. 314 pp.

Kobylinski, G.J., and P.F. Sheridan. 1979. Distribution, abundance, feeding and long-term fluctuations of spot, Leiostomus xanthurus, and croaker, Micropogonias undulatus, in Apalachicola Bay, Florida, 1972-1977. Contrib. Mar. Sci. 22:149-161.

Parker, J.C. 1971. The biology of spot, Leiostomus xanthurus Lacepede, and Atlantic croaker, Micropogon undulatus (Linnaeus), in two Gulf of Mexico nursery areas. Sea Grant Publ. No. TAMU-SG-71-210. Texas A&M Univ., College Station.

Pearson, J.C. 1929. Natural history and conservation of the redfish and other commercial sciaenids of the Texas coast. Bull. U.S. Bur. Fish. 44:129-214.

Perkins, E.J. 1974. The biology of estuaries and coastal waters. Academic Press, New York.

Roelofs, E.W. 1954. Food studies of young sciaenid fishes, Micropogon and Leiostomus, from North Carolina. Copeia 1954(2):151-153.

Root, R.B. 1967. The niche exploitation pattern of the blue-gray gnatcatcher. Ecol. Monogr. 37: 317-350.

Schwartz, F.J. 1964. Effects of winter water conditions on fifteen species of captive marine fishes. Am. Midl. Nat. 71(2):434-444.

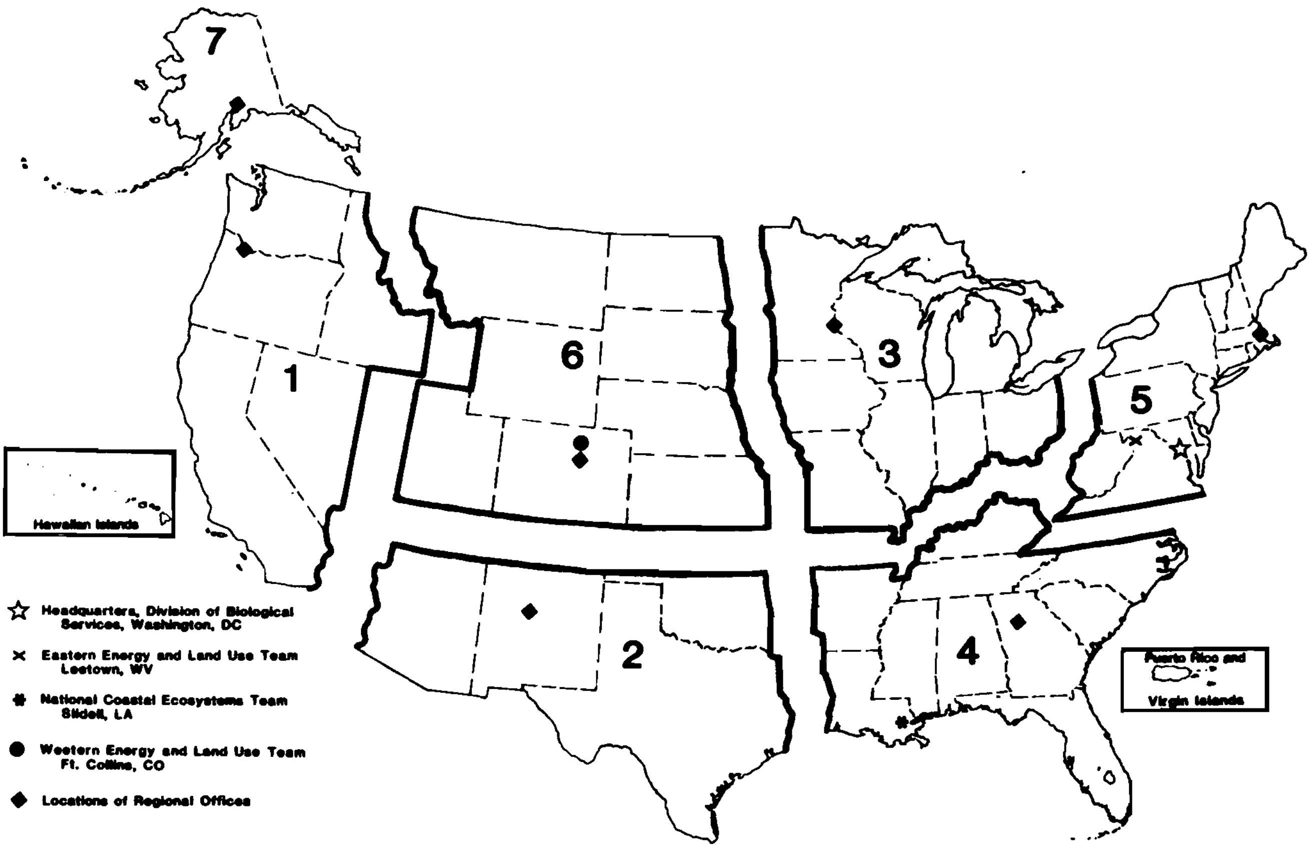
Simmons, E.G. 1957. An ecological survey of the Upper Laguna Madre of Texas. Publ. Inst. Mar. Sci. Univ. Texas. 41(2):156-200.

Stern, E.M., and W.B. Stickle. 1978. Effects of turbidity and suspended material in aquatic environments: literature review. U.S. Army Eng. Waterways Exp. Stn., DMRP Tech. Rep. D-78-21.

Suttkus, R.D. 1955. Seasonal movements and growth of the Atlantic croaker (Micropogon undulatus) along the east Louisiana coast. Proc. Gulf Caribb. Fish. Inst. 7:151-158.

Wallace, D.H. 1940. Sexual development of the croaker, Micropogon undulatus, and distribution of the early stages in Chesapeake Bay. Trans. Am. Fish. Soc. 70:475-482.

White, M.L., and M.E. Chittenden, Jr. 1977. Age determination, reproduction and population dynamics of the Atlantic croaker, Micropogonias undulatus. Fish. Bull., U.S. 75:109-123.



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